

Geographisches Institut der Universität Basel, Schweiz

Population dynamics of oribatid mites (Acari: Oribatei) in a forest soil ecosystem

RUDOLF SCHENKER

With 4 figures

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1. Introduction

The population density and species diversity of oribatid mites in soil ecosystems are greater than those of most other arthropod groups. Their energetic role varies considerably but is usually small in temperate systems. However, their regulatory role on fungal and bacterial populations is an important factor in the functioning of the soil system. To assess this function it is essential to understand the biology and population dynamics of this animal group. Data on the life histories of several oribatid species from both laboratory studies (LEBRUN 1970, MITCHELL 1977a, SCHATZ 1983, SENGBUSCH 1954) and field studies (MITCHELL 1977a, WEST 1982) are available. MITCHELL (1977b) has given a brief review of life history strategies of oribatid mites. Many field studies however, have considered only seasonal fluctuations or oribatids as an entity.

The aim of this paper is to provide field-data based life history parameters for some abundant oribatid species and to extend the information on oribatid ecology for different environments and species. In addition, the seasonal fluctuations of the oribatids is described for a forest soil ecosystem and compared with previous studies on oribatid dynamics (e.g. HARDING 1969, LUXTON 1981, MITCHELL 1977a, SOLHØY 1975).

This study was part of a larger investigation of a deciduous forest soil in north-west Switzerland undertaken during 1979—1980, which was concerned with the dispersion, abundance and population dynamics of oribatid mites (SCHENKER 1981). The spatial and seasonal distribution patterns have been described previously (SCHENKER 1984a).

2. Site description

The study was conducted in a mixed deciduous forest of the Querco-carpinetum association with planted pine trees, ca. 6 km south of Basel, Switzerland. The site at 380 m a.s.l. on a 2% slope contained three tree species characteristic of the forest, i.e. *Quercus robur* L., *Fagus sylvatica* L. and *Pinus silvestris* L. forming a triangle of ca. 12 m sidelength. **The tree species are referred to by their generic names hereafter.**

The soil, a well drained brown-parabrown-earth on loess, is covered by a small scale mosaic of mull and moder. A detailed description of the site is given by SCHENKER (1984a).

3. Methods

Soil and litter samples were collected monthly from February 1979 to February 1980. On each occasion, eight samples were taken from around each of the three trees at 30 cm distance and to a depth of 5 cm, which corresponded approximately to the *A_h*-layer of the humus. Faunal data from these samples were used for the analysis presented in this paper. The protocol of additional sampling is given in SCHENKER (1984a).

The soil arthropods were extracted in a modified high gradient Macfadyen extractor (BIERI *et al.* 1978) into isopropanol and separated and counted under a binocular microscope. Oribatid species and life stage identification was done using a high power microscope. Eggs were counted inside gravid females. Life tables were calculated according to KREBS (1978) and SOUTHWOOD (1978).

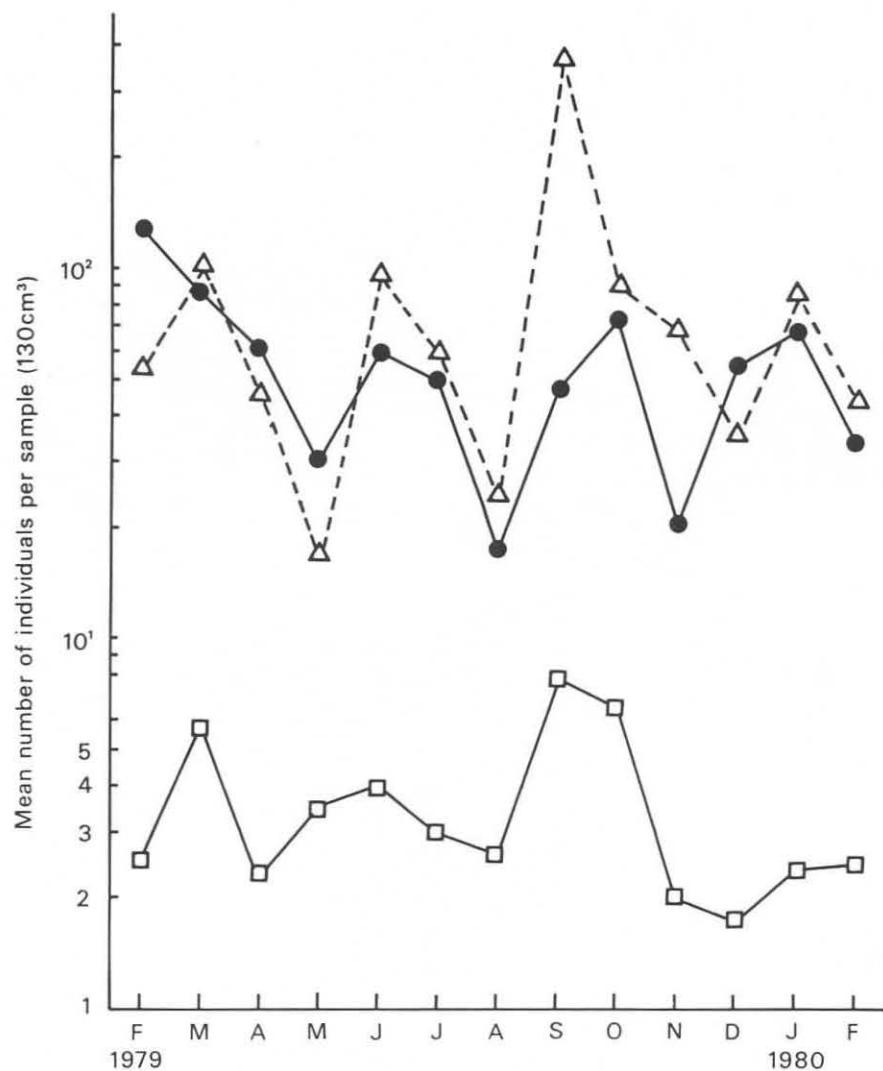


Fig. 1. Abundance of oribatid mites near *Quercus robur* (◻—◻), *Fagus sylvatica* (●—●) and *Pinus sylvestris* (△---△) at the study site.

4. Results

4.1. Seasonal population fluctuations

4.1.1. Total oribatids

The 65 oribatid species found during the study were unevenly distributed over the site, showing distinct patterns in relation to the tree species (SCHENKER 1984). This is partly reflected in Fig. 1 which demonstrates the oribatid dynamics over one year around each of the tree species. However, although there is a significantly lower oribatid density around *Quercus* compared to *Pinus* and *Fagus* the maxima and minima are within the same periods. The highest densities were observed in autumn (September to October) with smaller peaks in winter-spring (January to March) and summer (June to July).

4.1.2. Abundant species

Only a few species were extracted in sufficient numbers for the analysis of seasonal fluctuations and life history. These species were *Platynothrus peltifer* (Koch), *Tectocephalus velatus* (MICHAEL), *Oribatula tibialis* (NICOLET) and *Scheloribates pallidulus* (Koch). Other species such as *Brachychthonius berlesei* WILLMANN, *Oppiella nova* OUDEMANS and *Suctobelba subtrigona* (MICHAEL) also occurred in high numbers. However, the juvenile stages of these species were not extracted, probably due to their fragile nature, so they could not be included in this analysis.

The four abundant species were found over the whole site. However, *T. velatus* occurred almost exclusively around *Pinus* and was scarce at other places on the site (SCHENKER 1984b).

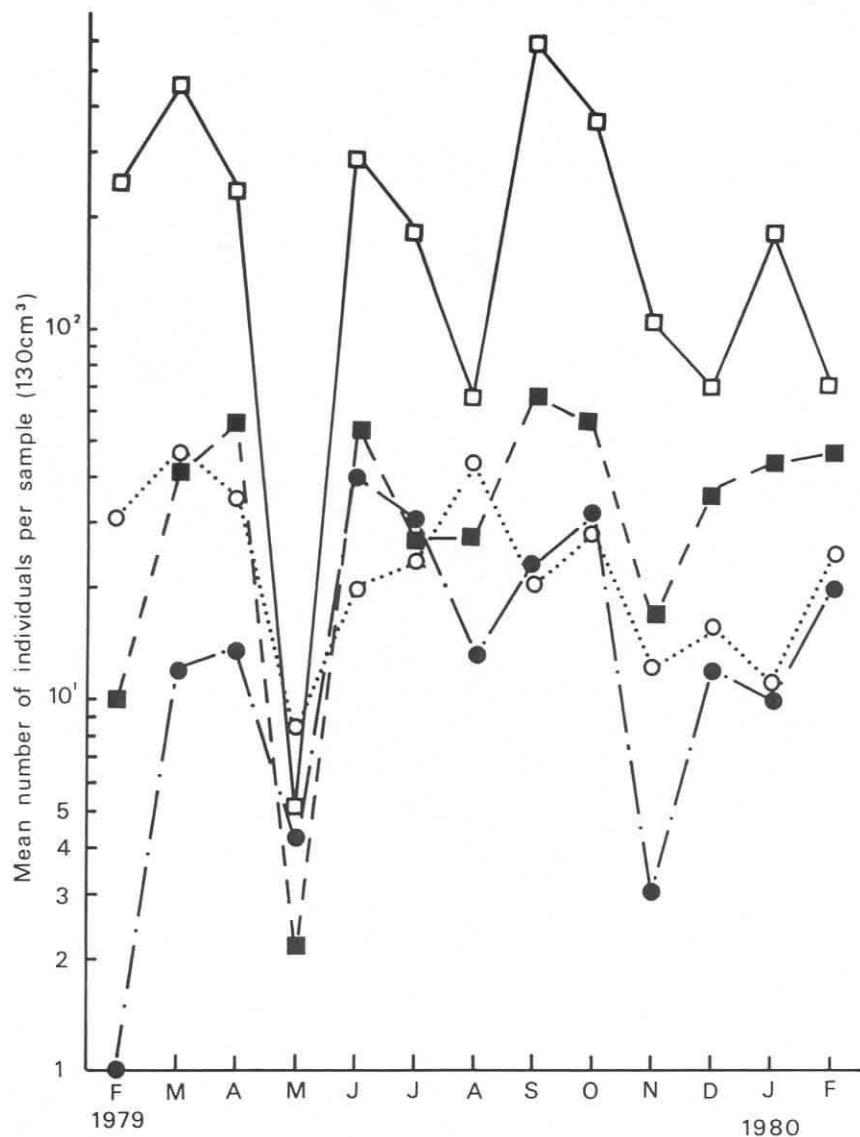


Fig. 2. Abundance of four oribatid species. □—□ *Tectocepheus velatus*, ■—■ *Oribatula tibialis*, ○—○ *Platynothrus peltifer*, ●—● *Scheloribates pallidulus* at the study site.

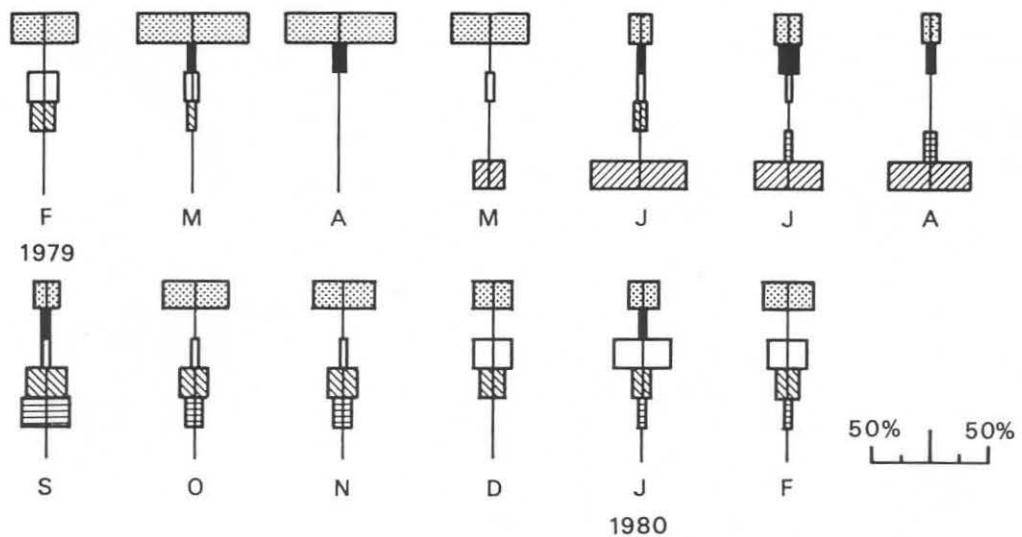
The seasonal dynamics showed a peak in spring (March to April) and autumn (September to October), except for *P. peltifer* which peaked in August (Fig. 2). The extreme minimum in May for all species is thought to be caused by the mild and very wet winter and spring months, followed by a cool and dry May.

4.2. Age class distribution

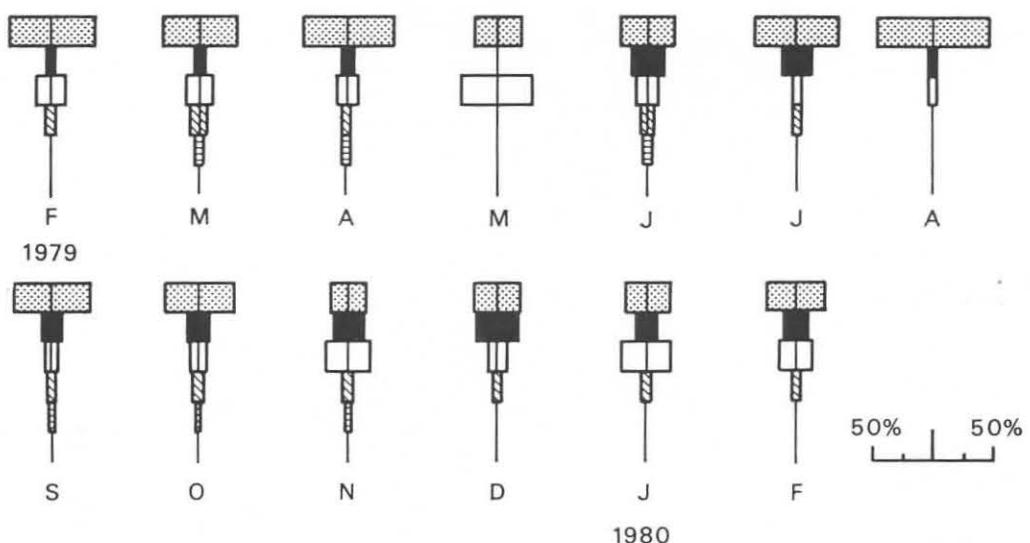
Three species were suitable for age class analysis (Fig. 3). The abundance of the various stages, however, may not represent absolute proportions. Younger stages of mites are often fragile, therefore they may be extracted in fewer numbers than adults. Thus the relative frequency of occurrence may be regarded only as an indicator of the phenology of the different species.

P. peltifer had one generation per year (Fig. 3a). The oviposition period being March to August, thereafter the development of the various stages can be seen in the changing proportion of their occurrence in the samples. It was not possible to count the eggs in gravid *T. velatus*. Changes of the age class distribution of the remaining stages (Fig. 3b), however, indicated two generations per year. Gravid females of *O. tibialis* occurred throughout the sampling period (Fig. 3c) except for February 1979 and August 1980. The juvenile stages of this species are particularly delicate, and only a few individuals were extracted. The fluctuation in numbers of adults and the occurrence of juveniles suggest that this species reproduces continuously throughout the year at this site.

a)



b)



c)

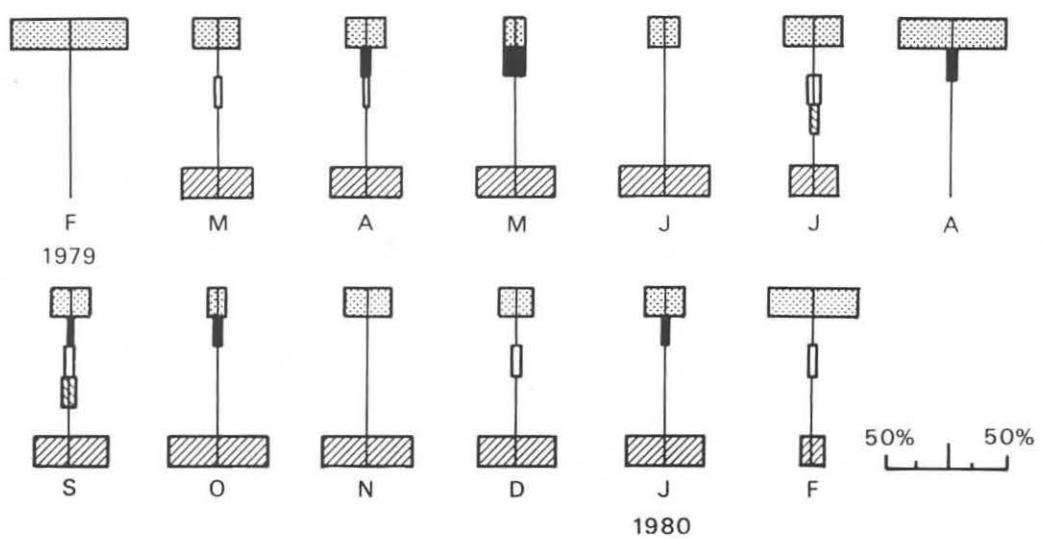


Fig. 3. Age class distribution in percentage of three oribatid species during the study period. (a) *Platyarthrus peltifer*, (b) *Tectocephalus velatus*, (c) *Oribatula tibialis*. Age classes: adults, tritonymphs, deutonymphs, protonymphs, larvae, eggs.

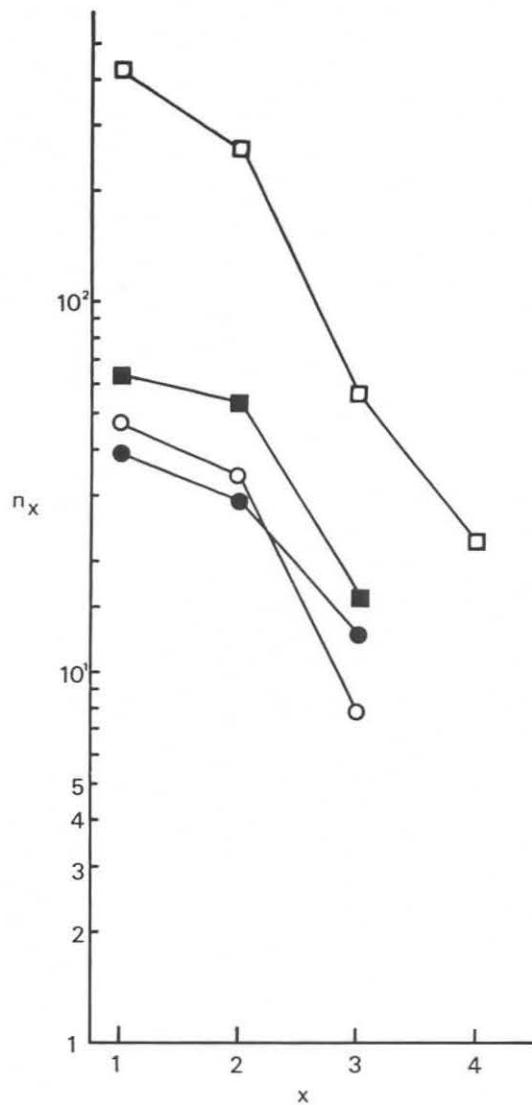


Fig. 4. Survivorship curves of four oribatid species. \square — \square *Tectocepheus velatus*, \blacksquare — \blacksquare *Oribatula tibialis*, \bullet — \bullet *Scheloribates pallidulus*, \circ — \circ *Platynothrus peltifer* (x = intervals in months, n_x = number of individuals at interval x).

4.3. Life tables

The data presented in the life tables are estimated by analysing the population fluctuations of adults in periods of population growth or decline. These periods lasted three and four months respectively (Table 1) after which the mean expectation of live e_x for an individual alive in this month remains half a month but mortality q_x is 100% during this month. In all species, the highest age specific fertility m_x occurs in the first part of adult life and later decreases slightly although it may fluctuate (Table 2). The high net reproductive rate R_0 would allow all species to multiply their population between 6.0 and 9.5 times per generation. In contrast, the innate capacity for increase r_m (Table 3) for that environment is much smaller.

Fig. 4 represents the last step of the survivorship curves for the adults of three species. Regarding the whole life span of these species, the survivorship curve may show several distinct steps, since mortality can vary considerably in the different stages, as was shown e.g. for *Oromurcia sudetica* (SCHATZ 1982). The same type of survivorship curve was found by LEBRUN (1970) in adults of *Nothrus palustris*.

Table 1. Age specific life tables for four oribatid species estimated from field data

	x	n _x	l _x	d _x	q _x	L _x	T _x	e _x
<i>Platynothrus peltifer</i>	1	47	1,000	12	0.26	41.0	66.5	1.41
	2	35	745	27	0.77	21.5	25.5	0.73
	3	8	170	8	1.00	4.0	4.0	0.50
<i>Tectocepheus velatus</i>	1	435	1,000	176	0.41	347.0	556.5	1.28
	2	259	595	202	0.78	158.0	209.5	0.81
	3	57	131	34	0.60	40.0	51.5	0.90
	4	23	53	23	1.00	11.5	11.5	0.50
<i>Oribatula tibialis</i>	1	63	1,000	10	0.16	58.0	100.5	1.60
	2	53	841	37	0.70	34.5	42.5	0.80
	3	16	254	16	1.00	8.0	8.0	0.50
<i>Scheloribates pallidulus</i>	1	40	1,000	10	0.25	35.0	63.0	1.58
	2	30	740	27	0.57	21.5	28.0	0.93
	3	13	325	13	1.00	6.5	6.5	0.50

Symbols: (x) age interval (months); (n_x) number of survivors at start of age interval x; (l_x) proportion of organisms surviving to start of age interval x; (d_x) number dying during age interval x to x + 1; (q_x) rate of mortality during the age interval x to x + 1; (L_x) number of individuals alive on the average during the age interval x to x + 1, $T_x = \sum_{x=0}^{\infty} L_x$; (e_x) mean expectation of life for individuals alive at the start of age x.

Table 2. Survivorship and fertility table for three oribatid species estimated from field data

	a	x	l _x	m _x	l _x m _x	R ₀
<i>Platynothrus peltifer</i>	0—1	0.5	1.00	5.05	5.05	
	1—2	1.5	0.48	4.70	2.26	
	2—3	2.5	0.55	2.61	1.44	
	3—4	3.5	0.19	0.38	0.07	
	4—5	4.5	0.48	—	—	8.82
<i>Oribatula tibialis</i>	0—1	0.5	1.00	1.76	1.76	
	1—2	1.5	0.84	5.66	4.75	
	2—3	2.5	0.25	1.44	0.36	
	3—4	3.5	0.59	2.11	1.24	
	4—5	4.5	0.41	3.27	1.34	
	5—6	5.5	0.73	—	—	9.46
<i>Scheloribates pallidulus</i>	0—1	0.5	1.00	3.00	3.00	
	1—2	1.5	0.75	3.80	2.85	
	2—3	2.5	0.33	0.31	0.10	
	3—4	3.5	0.10	0.75	0.08	
	4—5	4.5	0.58	—	—	6.03

Symbols: (a) age group; (x) pivotal age; (l_x) proportion surviving to pivotal age; (m_x) number of female offspring per female aged x per time unit; (R₀) net reproductive rate.

Table 3. Innate capacity for increase and finite rate of increase for three oribatid species

	r _m	λ
<i>Platynothrus peltifer</i>	1.36	2.31
<i>Oribatula tibialis</i>	1.06	2.89
<i>Scheloribates pallidulus</i>	1.62	1.68

Symbols: (r_m) innate capacity for increase for the particular environmental conditions; (λ) finite rate of increase.

5. Discussion

The assessment of the demography of oribatid field populations has several problems. Firstly, the intervals between sampling are crucial, as age classes or even whole generations may be missed in species with short generation times. Secondly, the extraction efficiency may vary for different species, probably being poor for younger stages, although VAN STRAALEN & RIJNINKS (1982) did not find juveniles of two *Collembola* species underestimated in efficiency experiments. Thirdly, field temperature may influence the duration of the different life stages, a fact not accounted for in laboratory studies.

The phenology observed in the four most abundant species at the Swiss forest site is comparable to that in other habitats. For example, gravid females of *P. peltifer* occur from May to August, which was also found by HARDING (1971) in field cultures.

The additional information from life tables provides the innate parameters of the dynamics of these species. The large fluctuations of all species may be explained by the high net reproductive rate R_0 followed by a high mortality. The former feature enables the oribatids to take advantage of favourable environmental conditions when they occur, which results in a multiplication of their population size by a factor of 6 to 9.5 within one generation. Thus new resources (litter etc.) are utilized efficiently.

The theoretical growth R_0 of *P. peltifer*, *O. tibialis* and *S. pallidulus* (Table 2) is much higher than the growth potential r_m realized under the natural climatic and food conditions (Table 3). The ratio r_m/R_0 for *P. peltifer* is 0.15, i.e. only about 15% of the theoretical growth is realized under the environmental conditions at the site. For *O. tibialis* this ratio is 0.11, whereas *S. pallidulus* can achieve 27% of its potential growth under the present conditions. This also suggests that conditions at the site favour *S. pallidulus* of the three species examined. However, because it has the lowest R_0 (6.0) this species has also the lowest λ in spite this.

A comparison between these field data and the literature data based on laboratory studies, sometimes combined with field studies (e.g. LEBRUN 1970, HARDING 1971), shows that this approach can be useful. It will provide basic information on the population dynamics of oribatids, either as a basis for ecological estimates (energy flow, etc.), and/or as a foundation for more detailed laboratory studies.

6. Conclusions

The phenology of four species of oribatid mites derived from field data provide information on the processes underlying their population dynamics. All the species studied show a high net reproductive rate enabling their populations to increase rapidly when environmental conditions are favourable. On the other hand, high mortality rates were observed, which, in combination with the high R_0 , may explain the large seasonal fluctuations in the total numbers of oribatids. Therefore, the resulting innate capacity for increase is relatively low. Underlying these fluctuations is a distinct seasonality in the generations. *P. peltifer* has one generation per year, *T. velatus* has two, whereas *O. tibialis* reproduces throughout the year. These results coincide with laboratory studies and confirm that this approach is useful as a tool for direct ecological assessments and provides a foundation for more detailed laboratory studies.

7. Zusammenfassung

In einer Querco-Carpinetum Assoziation mit eingepflanzten Föhren wurden vom Februar 1979 bis Februar 1980 monatlich Proben um die für drei für den Standort typischen Baumarten genommen. Die saisonalen Fluktuationen der 65 nachgewiesenen Oribatidenarten werden dargestellt, ebenso wie die Phänologie der vier häufigsten Arten. Für diese Arten wurden auch einige Parameter ihrer Populationsdynamik aufgrund der Feldbeobachtungen geschätzt. Gemäß der Altersklassenverteilung in den Proben hatte *P. peltifer* eine Generation pro Jahr, *T. velatus* deren zwei, während sich *O. tibialis* über das ganze Jahr fortpflanzte. Die relativ hohe Nettoreproduktionsrate und die durch die Umweltbedingungen am Standort verursachte hohe Mortalität, führen zu den beobachteten großen Populationsschwankungen. Wie Vergleiche mit Literaturangaben zeigen, können auch auf Grund von Felddaten geschätzte Populationsparameter als Grundlage für weitere ökologische Berechnungen (Energiefluss usw.) und/oder zur Planung von detaillierten populationsdynamische Laboruntersuchungen verwendet werden.

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Address of the author: Dr. R. SCHENKER, Geographisches Institut, Universität Basel, Klingelbergstraße 16, CH - 4056 Basel, Schweiz (Switzerland).

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SCHENKER, R., 1986. Population dynamics of oribatid mites (Acari: Oribatei) in a forest soil ecosystem. *Pedobiologia* **29**, 239—246.

In a Querco-carpinetum forest association with planted pine trees, monthly samples were taken from February 1979 to February 1980 from around three characteristic tree species. The seasonal population fluctuations of 65 oribatid mite species are described together with the phenology of the four most abundant species. Life table parameters such as survivorship, fertility and rates of increase were estimated from field data for these species. The age class distribution of *P. peltifer* suggested a single generation per year, two generations p.a. for *T. velatus*, whereas *O. tibialis* reproduces throughout the year. The relatively high net reproductive and mortality rates caused by the environmental conditions at the forest site, account for the gross population changes. This approach, based on field data, can be used for further ecological estimates (energy flow, etc.) and as a foundation for more detailed laboratory studies.

Key words: Acari, Oribatei, population dynamics, life tables, forest soil.